Orthotic interventions to improve standing balance in somatosensory loss

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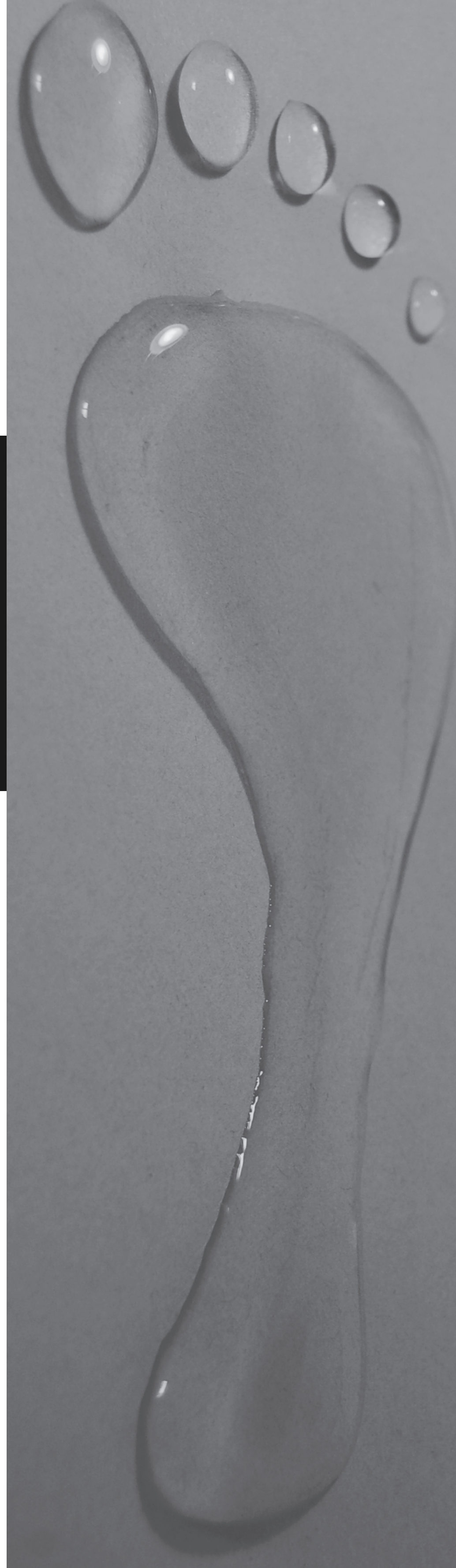
Summary



Balance in people with somatosensory loss is impaired because of decreased tactile and proprioceptive feedback from the lower limbs. The two largest groups of people with sensory loss because of peripheral nervous system disorders are older people and people with diabetic neuropathy (DN). In this thesis, focus was on balance in people with somatosensory loss and on possibilities to improve balance by enhancing somatosensory feedback from the lower limbs with ankle and foot appliances.

In *Chapter 2,* all publications investigating the effects of ankle and/or foot appliances (AFA) on balance in older people (≥ 60 years) and patients with peripheral nervous system disorders (PNSD) were identified and reviewed. The two groups account for the majority of the population with deteriorated balance due to peripheral somatosensory feedback problems. To provide a context for understanding and interpreting the studies published to date, current theories on the role of somatosensory mechanisms in control of balance and how balance can be affected by AFA were briefly summarized. A systematic literature review was presented in which publications were searched in Medline, Embase and Recal. In total 146 papers were identified from which 18 were selected based on title and abstract for qualitative assessment by two independent reviewers. Seven of these 18 papers fulfilled predetermined qualitative criteria and were selected for detailed review. No definitive conclusions could be drawn concerning the effects of AFA on balance in older people or in patients with PNSD because of the small number of studies and the weak level of evidence. The available literature indicated that a training program may be helpful in ensuring the effectiveness of an appliance. Insoles with tubing or vibrating elements may improve balance, whereas thick or soft soles may deteriorate balance. The effects of these different types of insoles or soles are consistent with theories about somatosensory mechanisms that play a role in control of balance. More and better quality research is needed to support the prevalent use of appliances in these populations.

The results from the review presented in *Chapter 2* guided the research in the chapters following. In *Chapter 3* the effects of foot and ankle compression on joint position sense (JPS) and balance in older people and young adults was studied. Twelve independently living healthy older persons (77-93y) were recruited from a senior accommodation facility. Fifteen young adults (19-24y) also participated. Compression was applied at the ankles and feet using medical compression hosiery. The mean velocity of the centre of pressure (COP) displacements and the root mean square of the COP velocity, in both anteroposterior and mediolateral directions, were measured with a foot pressure plate. In older people, ankle compression was associated with an improvement of JPS towards normal values. However, a concurrent deterioration of their balance was found. In young adults compression had no effect on either JPS or balance.

The objective of C*hapter 4* was to investigate the effects of sub threshold mechanical noise, applied to the plantar surface of the feet, on standing balance in subjects with neuropathy and healthy subjects. The noise was applied by vibrating insoles. The mechanism in which somatosensation is improved by the addition of noise is based on a phenomenon called stochastic resonance. When mechanical noise is applied together with other forces (changing pressure on the plantar surface of the foot during stance) information processing to the central nervous system is thought to be driven by the combination of the two forces. These forces cooperate in order to cross a certain threshold which under normal circumstances would not have been crossed. In four different conditions (eyes open or closed and with or without an attention demanding task) subjects with DN (n=17) and healthy subjects (n=15) stood for 60s on vibrating insoles placed on a force plate. During each condition the insoles were turned on for 30s and off for 30s (random order). The calculated balance measures were mean velocity of the centre of pressure displacements and root mean square of the velocity of these displacements in anteroposterior direction and mediolateral direction. In subjects with neuropathy, an interaction effect on balance was found between vibration and an attention demanding task. No effects of vibration on balance were found in healthy subjects. Vibrating insoles improved standing balance only in subjects with neuropathy and only when attention was distracted. Improvement of the insoles and their activation is needed to make implementation in daily living possible and effective.

In order to improve the effectiveness of the vibrating insoles used in *Chapter 4*, the development of vibrating insoles that are thought to have an increased ability to improve balance, was presented in the following chapter. This study described the requirements for the tactors (tactile actuators), insole material and noise generator. A search for the components of vibrating insoles providing mechanical noise to the plantar surface of the feet was performed. The mechanical noise signal should be provided by tactors built in an insole or shoe and should obtain an input signal from a noise generator and an amplifier. Possible tactors are electromechanical tactors, a piezoelectric actuator, or the VBW32 Skin Transducer. The Minirator MR1 of NTI, a portable MP3 player, or a custom made noise generator can provide these tactors with input, amplified by a custom made amplifier. The tactors can be built in foam, silicone, or cork insoles. A C2 electromechanical tactor, a piezoelectric actuator, or the VBW32 Skin Transducer, activated by a custom made noise generator, built in a cork insole with a leather cover layer seems the ideal solution.

In *Chapter 6* the most effective properties of a mechanical noise signal applied to the plantar surface of the feet were determined. As in the previous chapters, the noise was applied by vibrating insoles, in order to improve standing balance in people with DN. In a single case experimental approach (n=5) the effects on balance of mechanical noise were studied. Noise was applied at three different amplitudes and was low pass filtered with three different cut-off frequencies (nine different interventions). Mean velocity of centre of pressure displacement, measured using a force plate, was used as the measure of balance. The effects of the nine different noise levels were compared with both the interval before and the interval after. The results showed that mechanical noise applied to the feet by vibrating insoles can improve balance in people with minor to moderate neuropathy. Noise, low pass filtered with a cut-off frequency of 200Hz seemed to be the most effective in improving balance; the applied amplitude with this cut-off frequency seemed arbitrary.

In *Chapter 7* the impact of the research presented in this thesis is discussed. Recent literature provided information about more orthotic possibilities to improve balance in people with somatosensory loss. Moreover, other options to improve balance in people with somatosensory loss were presented. From this thesis, it can be concluded that although ankle compression improves JPS, it caused balance to deteriorate concurrently. Insoles providing mechanical noise to the plantar surface of the feet improve balance. However, these insoles can not yet be applied in daily practice. In future, research should focus on the development of a vibrating insole system that can be used in daily practice and on other interventions to improve plantar sensation.